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JPL HYPERSPECTRAL IMAGE ANALYSIS PROGRAM

- BACKGROUND - IMAGING SPECTROMETRY IS BOTH QUANTITATIVELY AND QUALITATIVELY DIFFERENT FROM TRADITIONAL MULTISPECTRAL REMOTE SENSING IMAGERY

- IMPACTS ON SCIENCE USERS:

  - VISUAL INTERACTION WITH IMAGE DATA

  - VISUAL INTERACTION WITH SPECTRAL INFORMATION

  - TRADITIONAL STATISTICAL ANALYSIS METHODS BECOME SEVERELY COMPUTE BOUND

  - DATA MANAGEMENT AND SELECTION OF SPECTRAL COVERAGE FOR SPECIFIC ANALYSES

  - PHYSICAL MODELS TO ADEQUATELY DESCRIBE THE DATA

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JPL HYPERSPECTRAL IMAGE ANALYSIS PROGRAM

- PROGRAM OBJECTIVES

  - DEVELOPMENT OF EFFICIENT INTERACTIVE EXPLORATORY ANALYSIS TOOLS

  - DEVELOPMENT OF EFFICIENT QUANTITATIVE INFORMATION EXTRACTION ALGORITHMS FOR IMAGING SPECTROMETRY

  - APPLICATION OF EXPERT SYSTEM METHODS TO BUILDING AN INTEGRATED DATA MANAGEMENT/ANALYSIS SYSTEM

  - IDENTIFICATION AND UTILIZATION OF EMERGING HARDWARE TECHNOLOGY WHICH PROVIDE COST EFFECTIVE SOLUTIONS TO STORAGE AND ANALYSIS

JPL EXPERT SYSTEM FOR IMAGING SPECTROMETRY

- WHY AN EXPERT SYSTEM?

  - NEED INTEGRATED DATA MANAGEMENT AND ANALYSIS

  - ANALYSIS OF DATA REQUIRES INTELLIGENT GUIDANCE OF INTERACTIVE SESSION (CONSULTANT ROLE)

  - SPECTRAL INTERPRETATION CAN UTILIZE WELL-DEVELOPED INFERENCE RULES AND HEURISTICS

  - INTELLIGENT MANAGEMENT OF AVAILABLE COMPUTATIONAL RESOURCES

  - SYSTEM CAN BE TAILORED (DYNAMICALLY) TO FIT THE NEEDS OF SPECIFIC USERS
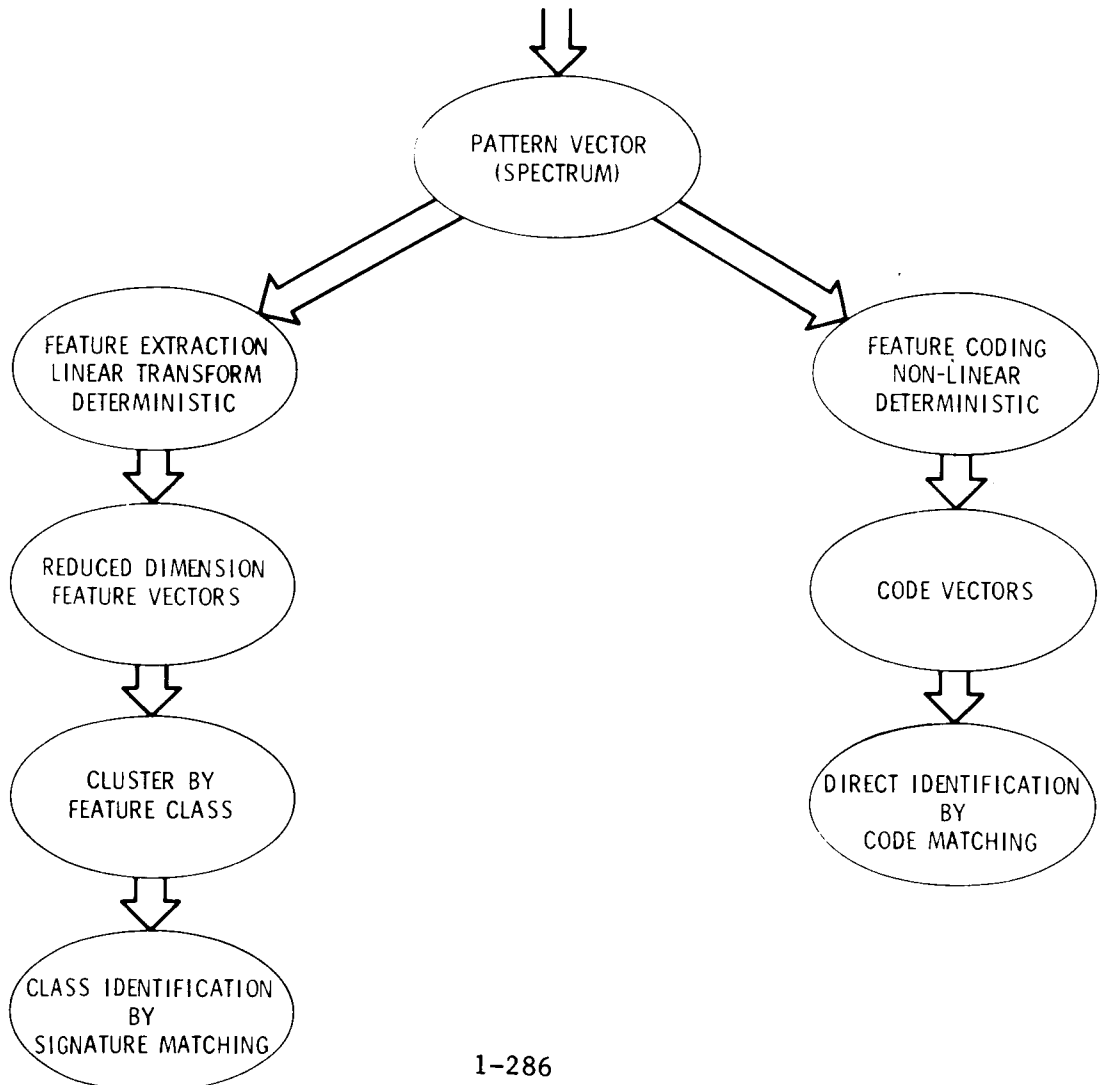
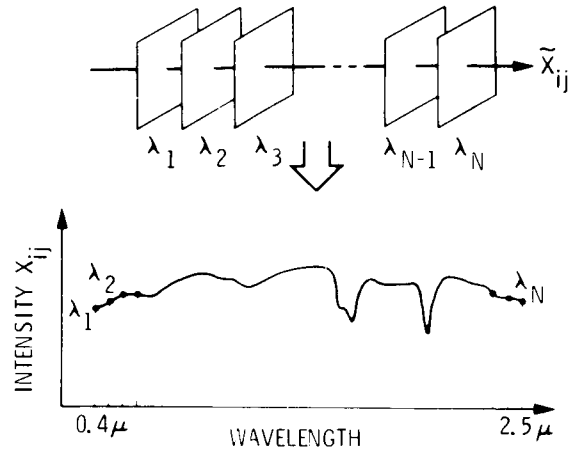# JPL EXPERT SYSTEM FOR IMAGING SPECTROMETRY

- FUNCTIONAL CAPABILITIES

  - INTERACTIVE WITHOUT EXHAUSTIVE INTERROGATION OF THE USER - CRISP "FRIENDLY" DIALOGUE

  - INTEGRATED USE OF GRAPHICS AND IMAGE DISPLAY

  - MULTI-MODE USAGE:

    - "DUM B"
    - SMART ADVISOR
    - AUTONOMOUS EXPERT

  - DYNAMICALLY MODIFIABLE KNOWLEDGE BASE

    - USER MODE
    - "MASTER" MODE

  - CAN BE RUN IN GENERAL COMPUTING ENVIRONMENT, I.E., NON-LISP HARDWARE

JPL EXPERT SYSTEM FOR IMAGING SPECTROMETRY

- TECHNICAL APPROACH

  - IMPLEMENTATION OF C-BASED EXPERT SYSTEM DESIGN TOOL

  - UTILIZE SEMANTIC NETWORK STRUCTURE FOR KNOWLEDGE REPRESENTATION

  - COMBINE SYMBOLIC/NUMERICAL COMPUTING TECHNIQUES

  - ORIENT SYSTEM AROUND VISUAL DISPLAY OF INFORMATION

  - CONCENTRATE DESIGN ON GEOLOGY APPLICATIONS

    - SPECTRAL KNOWLEDGE BASE MATURE

    - WELL DEVELOPED INFERENCE RULES AND HEURISTICS
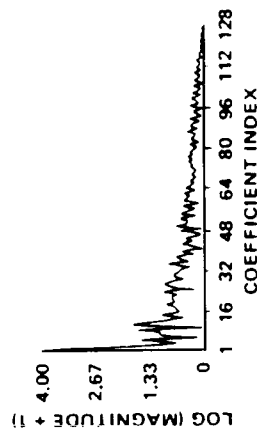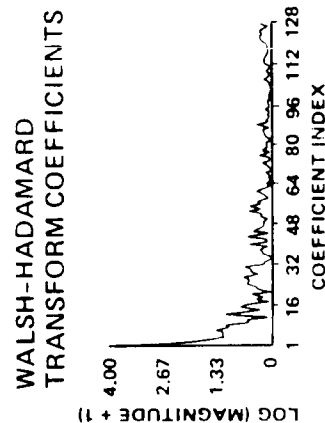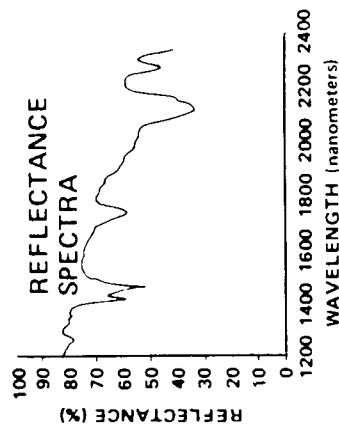
    - LOCALLY AVAILABLE "EXPERTS"

IMAGING SPECTROMETER
DATA ANALYSIS METHODS

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N-DIMENSIONAL PATTERN SPACE
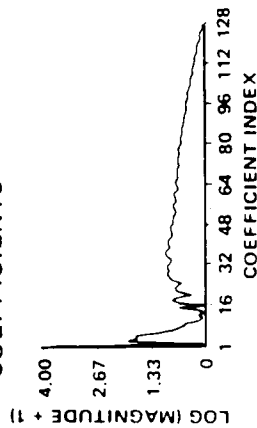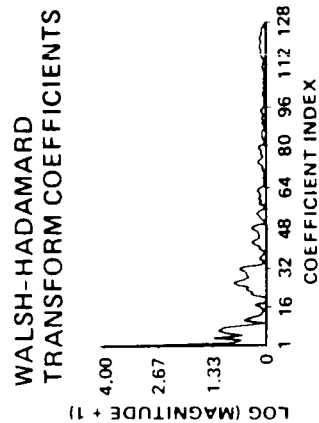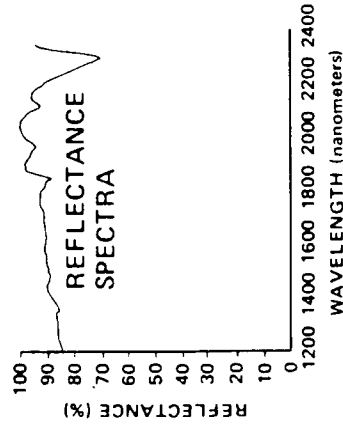

PATTERN VECTOR
(SPECTRUM)

FEATURE EXTRACTION
LINEAR TRANSFORM
DETERMINISTIC

FEATURE CODING
NON-LINEAR
DETERMINISTIC

REDUCED DIMENSION
FEATURE VECTORS

CODE VECTORS

CLUSTER BY
FEATURE CLASS

DIRECT IDENTIFICATION
BY
CODE MATCHING

CLASS IDENTIFICATION
BY
SIGNATURE MATCHING

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IMAGING SPECTROMETER
DATA ANALYSIS METHODS

- DETERMINISTIC LINEAR TRANSFORM AND CURVE-FITTING METHODS

REFLECTANCE SPECTRA

REFLECTANCE (%)

100 90 80 70 60 50 40 30 20 10 0

1200 1400 1600 1800 2000 2200 2400
WAVELENGTH (nanometers)

WALSH-HADAMARD TRANSFORM COEFFICIENTS

LOG (MAGNITUDE + 1)

4.00 2.67 1.33 0

1 16 32 48 64 80 96 112 128
COEFFICIENT INDEX

CHEBYSHEV POLYNOMIAL COEFFICIENTS

LOG (MAGNITUDE + 1)

4.00 2.67 1.33 0

1 16 32 48 64 80 96 112 128
COEFFICIENT INDEX

ALUNITE MINERAL SAMPLE

REFLECTANCE SPECTRA

REFLECTANCE (%)

100 90 80 70 60 50 40 30 20 10 0

1200 1400 1600 1800 2000 2200 2400
WAVELENGTH (nanometers)

WALSH-HADAMARD TRANSFORM COEFFICIENTS

LOG (MAGNITUDE + 1)

4.00 2.67 1.33 0

1 16 32 48 64 80 96 112 128
COEFFICIENT INDEX

CHEBYSHEV POLYNOMIAL COEFFICIENTS

LOG (MAGNITUDE + 1)

4.00 2.67 1.33 0

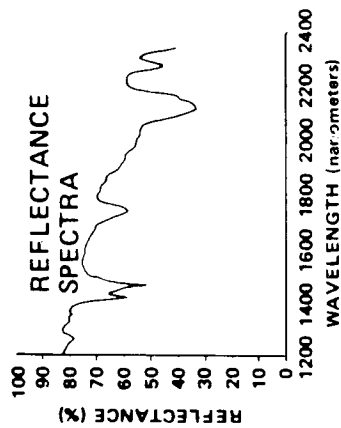1 16 32 48 64 80 96 112 128
COEFFICIENT INDEX
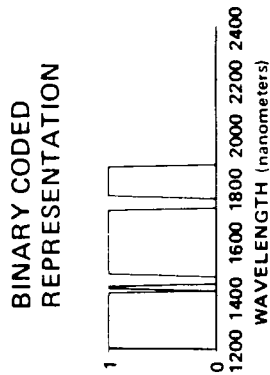
CALCITE MINERAL SAMPLE

- SPECTRAL DIMENSIONALITY CAN BE REDUCED WITHOUT LOSING SIGNATURE UNIQUENESS
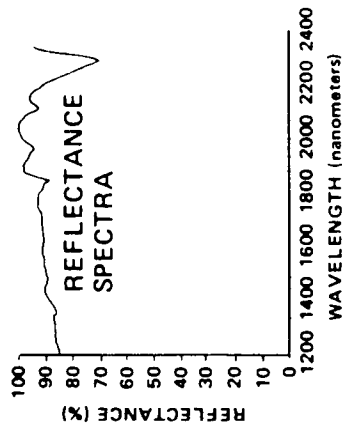
IMAGING SPECTROMETER
DATA ANALYSIS METHODS

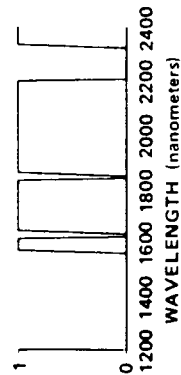**JPL**

- NON-LINEAR FEATURE CODING METHODS

REFLECTANCE SPECTRA

REFLECTANCE (%)
100 90 80 70 60 50 40 30 20 10 0

WAVELENGTH (nanometers)
1200 1400 1600 1800 2000 2200 2400

BINARY CODED REPRESENTATION

WAVELENGTH (nanometers)
1200 1400 1600 1800 2000 2200 2400

ALUNITE MINERAL SAMPLE

REFLECTANCE SPECTRA

REFLECTANCE (%)
100 90 80 70 60 50 40 30 20 10 0

WAVELENGTH (nanometers)
1200 1400 1600 1800 2000 2200 2400

BINARY CODED REPRESENTATION

WAVELENGTH (nanometers)
1200 1400 1600 1800 2000 2200 2400

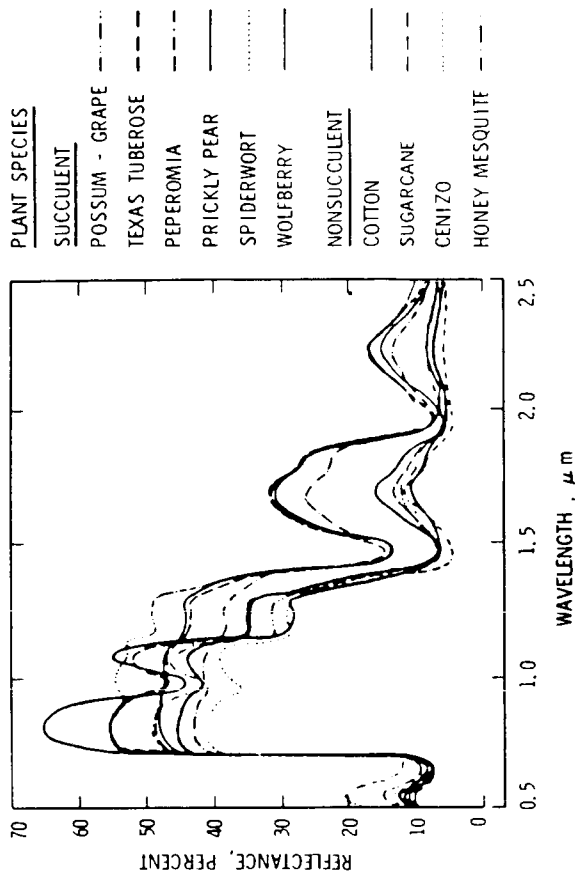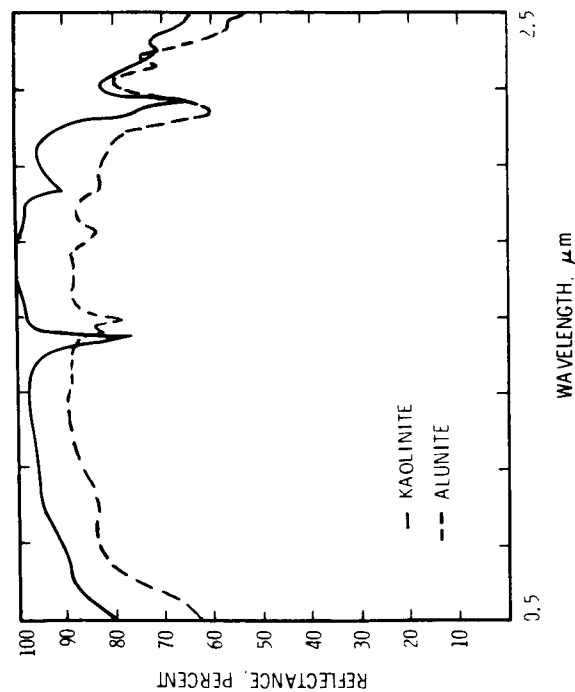CALCITE MINERAL SAMPLE

DIRECT BINARY ENCODING

- PRESERVES SIGNATURE UNIQUENESS
- EXTREMELY FAST CROSS-MATCHING CAPABILITIES
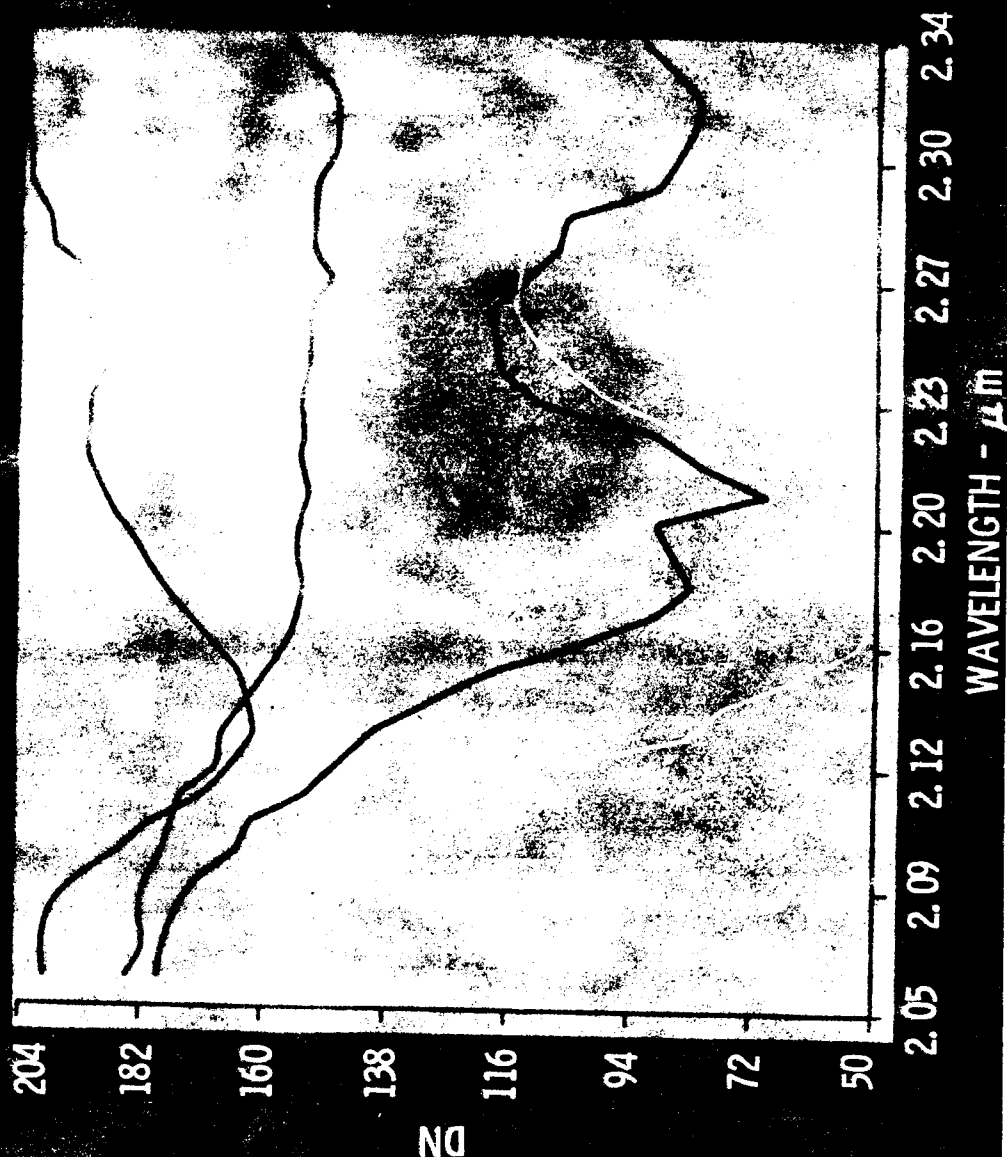
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IMAGING SPECTROMETER
DATA ANALYSIS METHODS

- SUITABILITY OF APPROACHES - MINERALS vs. VEGETATION

REFLECTANCE, PERCENT

KAOLINITE
ALUNITE

WAVELENGTH, μm

REFLECTANCE, PERCENT

WAVELENGTH, μm

PLANT SPECIES

SUCCULENT

POSSUM - GRAPE
TEXAS TUBEROSE
PEPEROMIA
PRICKLY PEAR
SPIDERWORT
WOLFBERRY

NONSUCCULENT

COTTON
SUGARCANE
CENIZO
HONEY MESQUITE

- ROCK/MINERAL SPECTRA SUITABLE FOR FEATURE CODING AND DIRECT IDENTIFICATION
  NON-LINEAR APPROACH

- VEGETATION SPECTRA REQUIRE DETECTION OF MORE SUBTLE EFFECTS
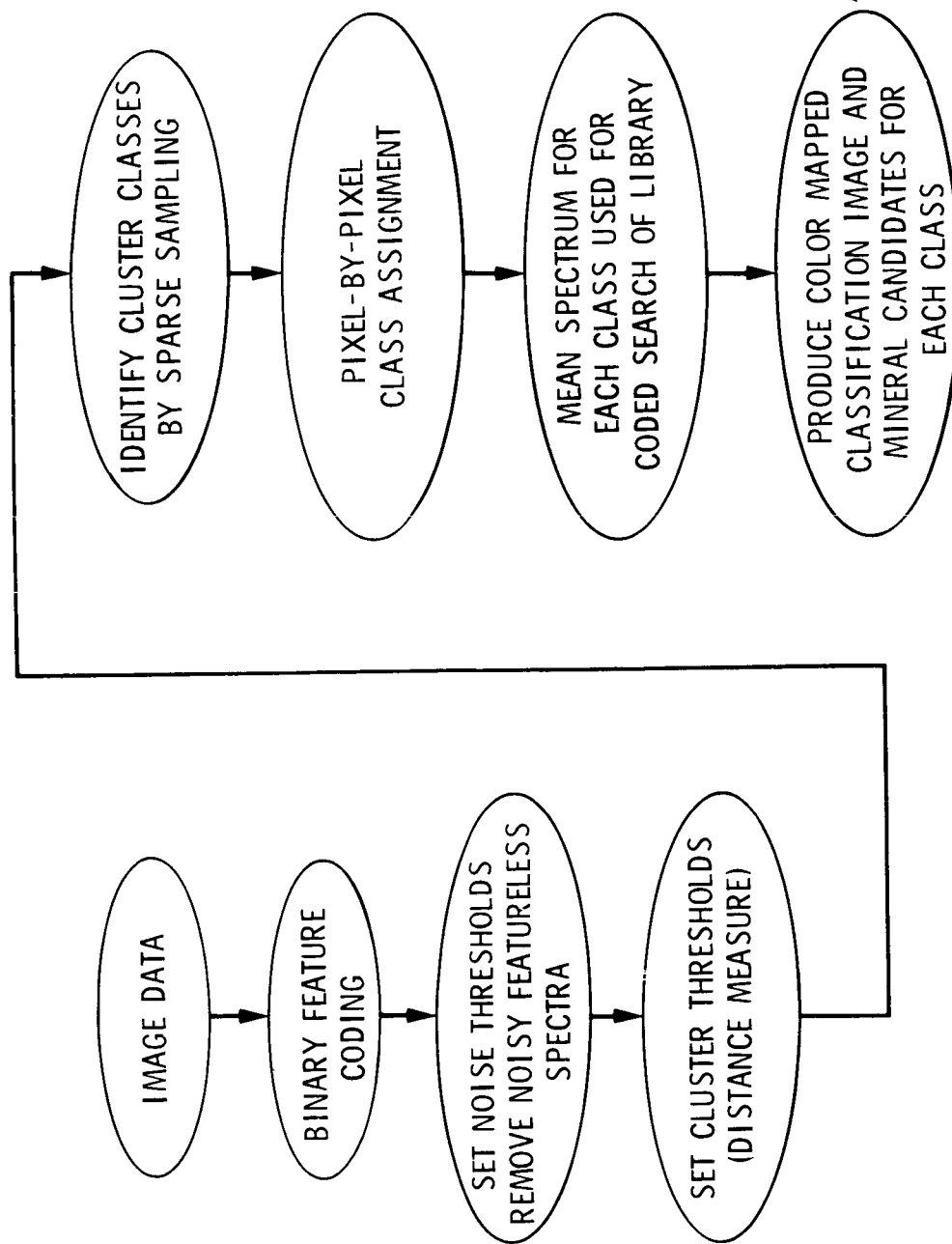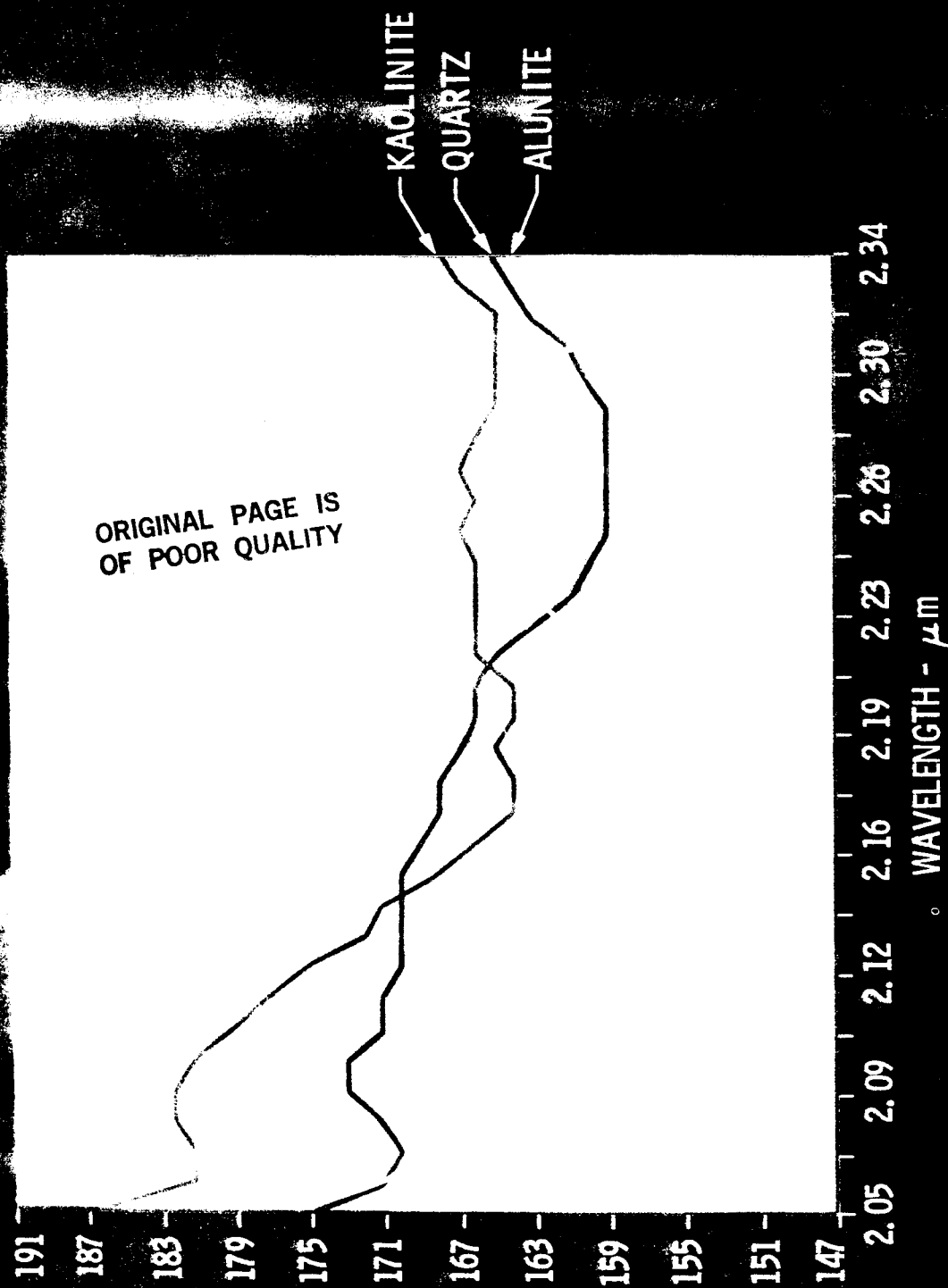 LINEAR TRANSFORM METHODS

CUPRITE, NEVADA
PIXEL SPECTRA

JPL

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IMAGING SPECTROMETER
DATA ANALYSIS METHODS

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- AUTOMATED MATERIALS IDENTIFICATION USING SPECTRAL LIBRARY

IMAGE DATA → BINARY FEATURE CODING → SET NOISE THRESHOLDS REMOVE NOISY FEATURELESS SPECTRA → SET CLUSTER THRESHOLDS (DISTANCE MEASURE)

IDENTIFY CLUSTER CLASSES BY SPARSE SAMPLING → PIXEL-BY-PIXEL CLASS ASSIGNMENT → MEAN SPECTRUM FOR EACH CLASS USED FOR CODED SEARCH OF LIBRARY → PRODUCE COLOR MAPPED CLASSIFICATION IMAGE AND MINERAL CANDIDATES FOR EACH CLASS

- THIS PROCESS REQUIRES ABOUT 2 MINUTES ON A SUN WORKSTATION FOR A 512 LINE IMAGE

CUPRITE, NEVADA
AUTOMATED SPECTRAL MAPPING

KAOLINITE
QUARTZ
ALUNITE

ORIGINAL PAGE IS
OF POOR QUALITY

WAVELENGTH - μm

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